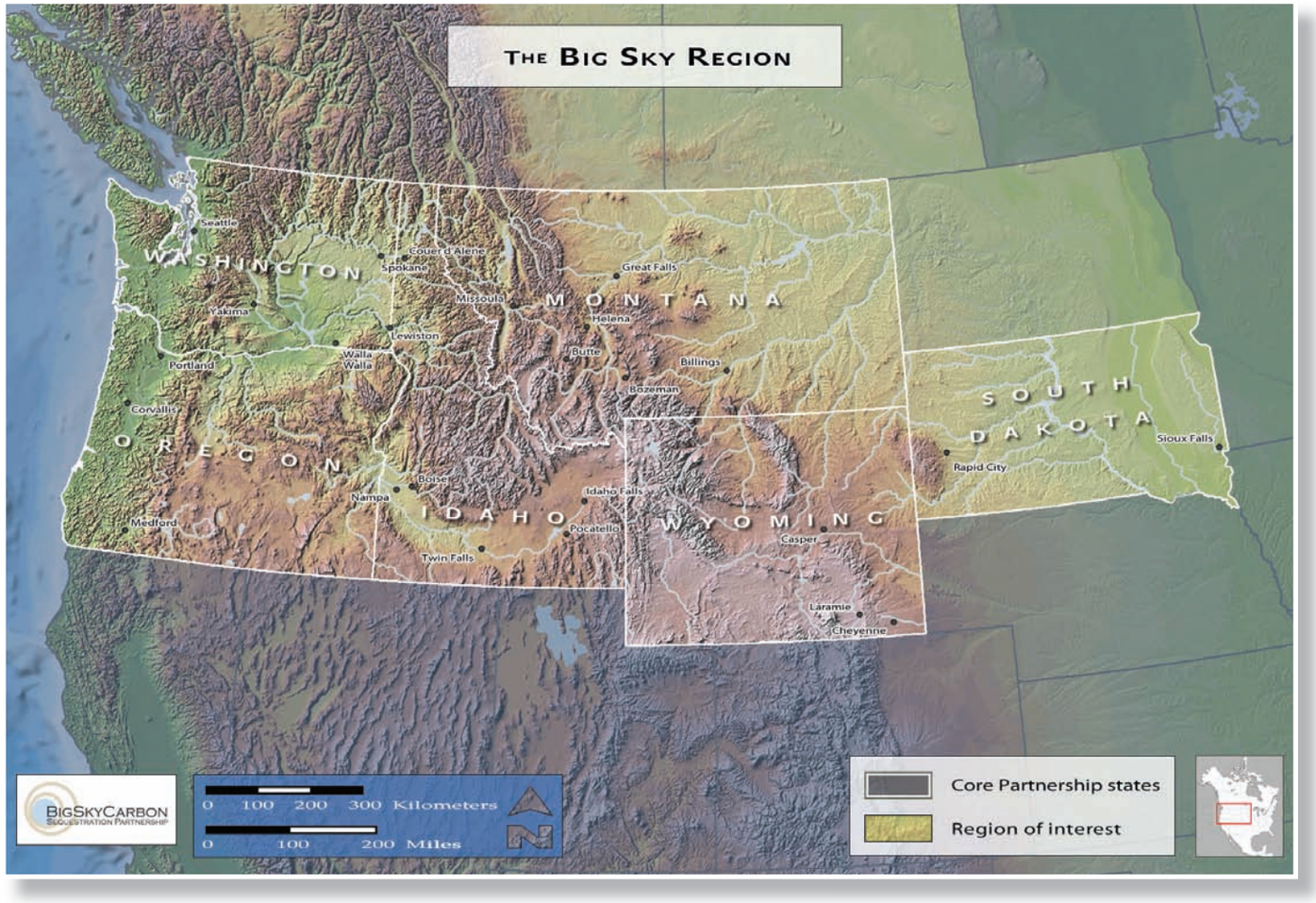
Big Sky Carbon Sequestration Partnership

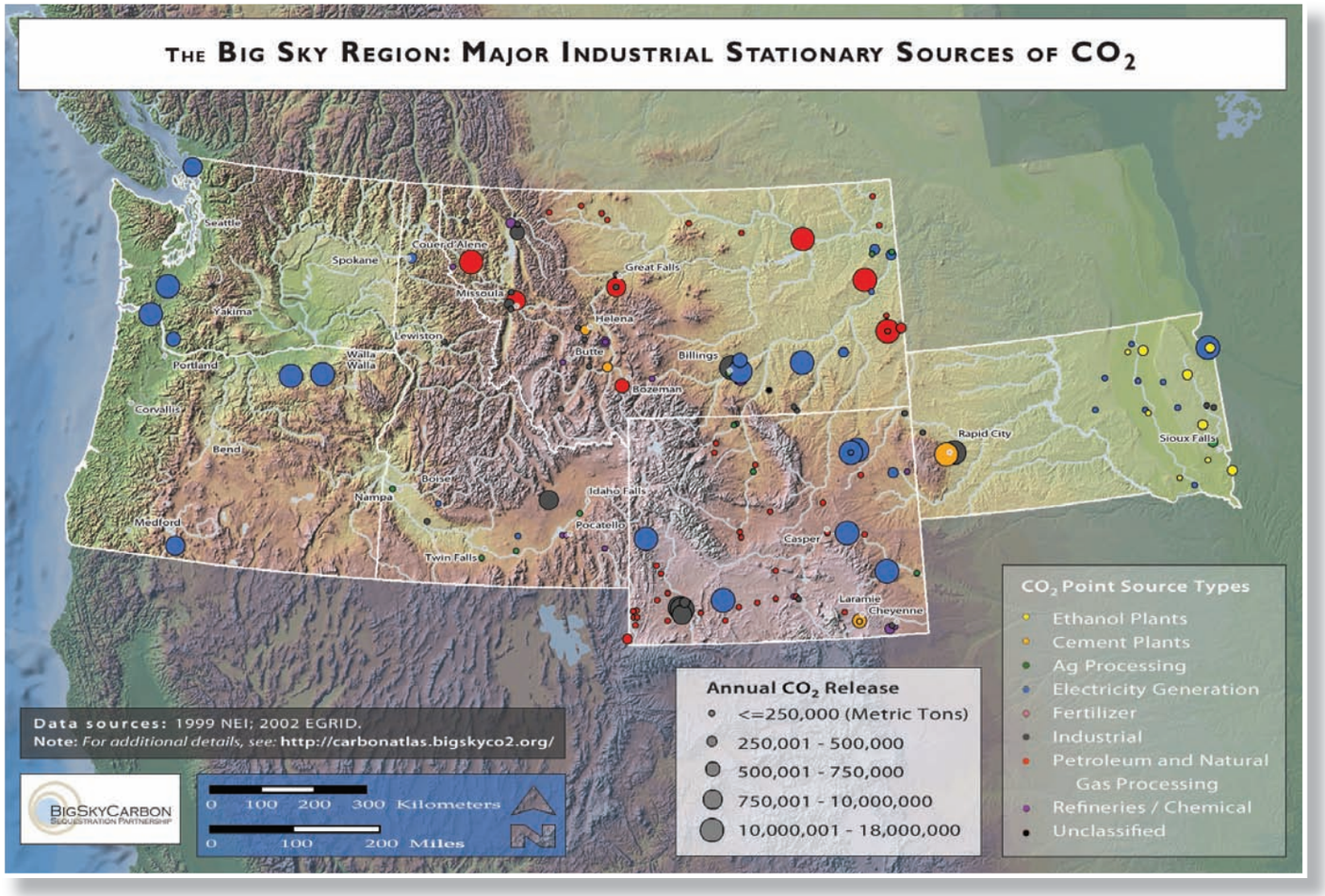


The Big Sky Carbon Sequestration Partnership (BSCSP) is building a new energy future for Montana, Idaho, South Dakota, Wyoming, eastern Oregon and Washington, and adjacent areas in British Columbia and Alberta. BSCSP is developing a framework to address CO_2 emissions and working with a diverse array of stakeholders to create the vision for a new, sustainable energy future that cleanly meets the Region's energy needs. BSCSP has the goal of developing an infrastructure to support and enable future carbon sequestration field tests and deployment throughout the BSCSP Region.

BSCSP represents a coalition of more than 60 organizations including universities and other research institutions, state and federal agencies, industry members including major power producers, carbon trading entities, state governments, outreach education partners, Tribal Nations and Councils, and international collaborators. Based at Montana State University, the BSCSP also benefits from the direct involvement of its partner institutions in Idaho.

The BSCSP Region has a diverse range of CO_2 sources and represents a wealth of potential carbon sequestration sites and future energy resources. Sequestration sites include large areas of mafic volcanic rocks (flood basalts), reactive carbonate reservoirs (e.g., the Madison formation), and Powder River basin coals. Potential energy resources include biomass and bioenergy alternatives, ethanol, natural gas reserves, the potential for nuclear power, and nearly 40 percent of total U.S. coal reserves.

BIGSKYCARBON
SEQUESTRATION PARTNERSHIP

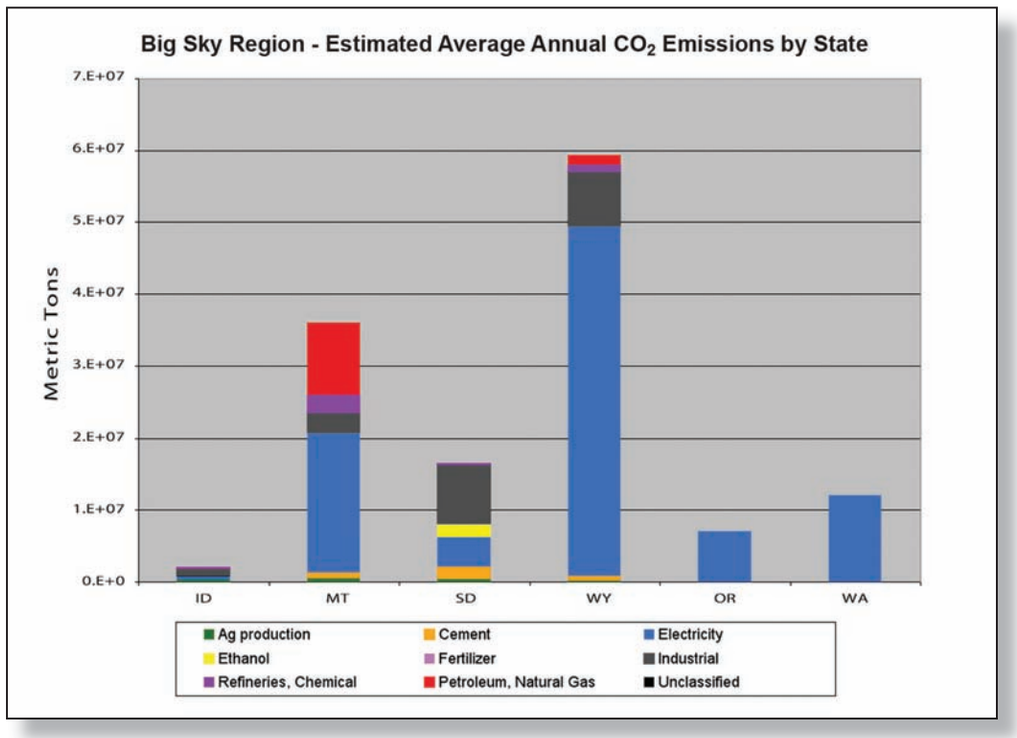


BSCSP Stationary Sources

The BSCSP has identified and characterized major industrial stationary sources of CO_2 within the Region, including ethanol plants, cement plants, agriculture processing, electricity generation, fertilizer production, industrial sources, petroleum and natural gas processing, refineries/chemical sources, and other unclassified sources.

Throughout the BSCSP Region, it is estimated that an average of 134 million metric tons (147 million tons) of CO_2 are emitted annually.

As part of ongoing activities related to construction of this *Atlas*, work continues to adequately characterize potential geological sequestration sites in the vicinity of stationary sources. This information, in conjunction with available infrastructure (pipelines, EOR sites, etc.) will provide an interactive mapping portfolio to allow siting of future plants in proximity to appropriate geological formations and infrastructure for sequestration purposes.



Stationary source GHG emissions.

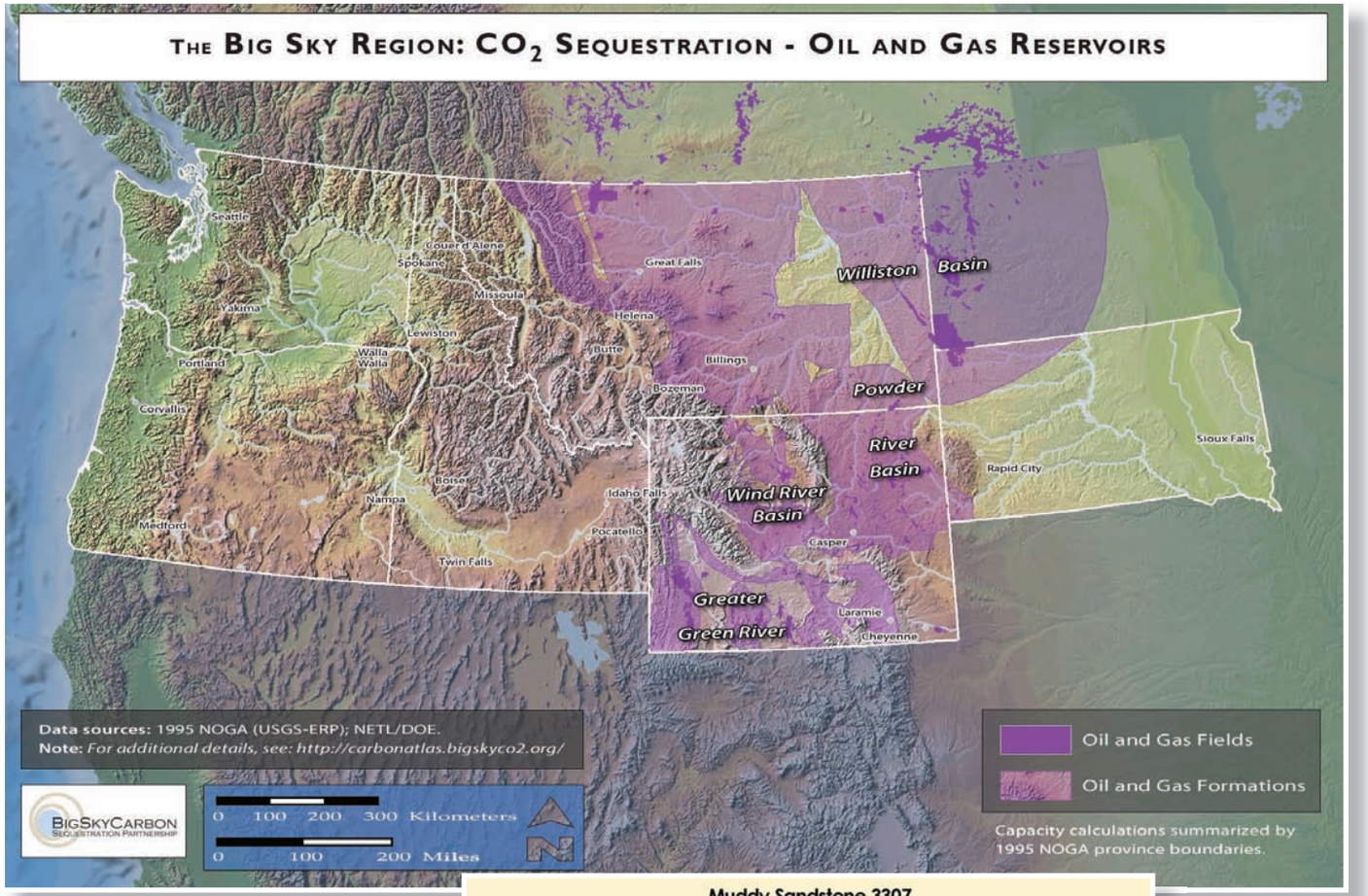
BSCSP Oil and Gas Reservoirs

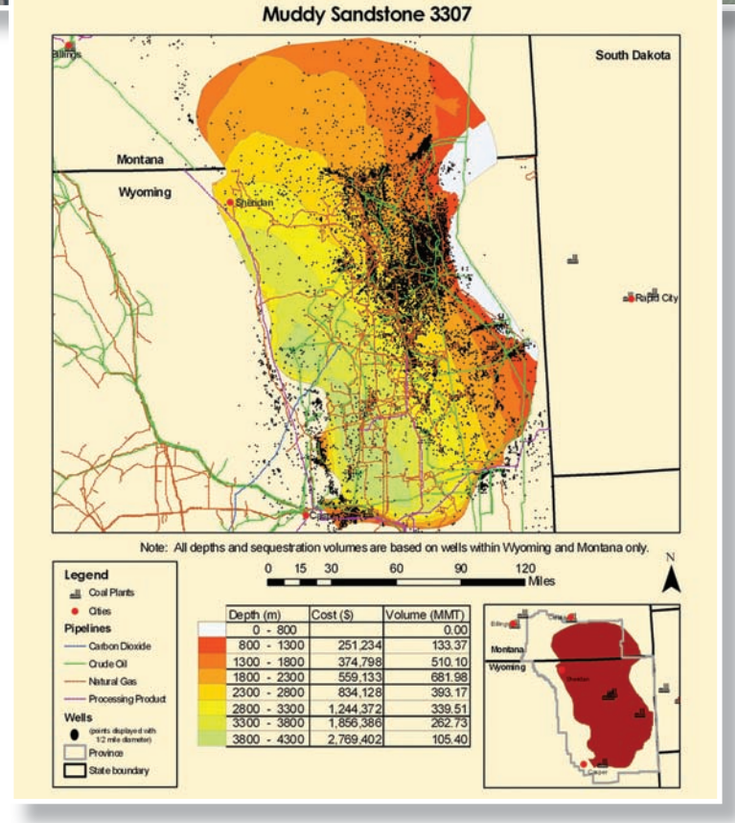
Mature oil and gas reservoirs that held crude oil and natural gas over millions of years, within the BSCSP Region, are found mostly in Wyoming and Montana and a small portion of South Dakota.

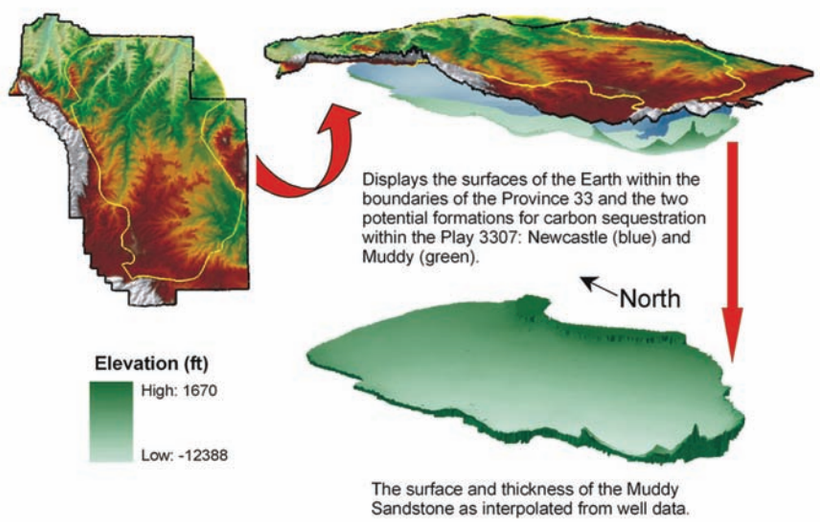
The major oil- and gas-producing basins within the Region are the Williston basin that covers the eastern edge of Montana and parts of South and North Dakota, the Wind River basin that sits completely inside Wyoming, the Powder River basin that overlaps the southeastern corner of Montana and the northwestern corner of Wyoming, and finally, the Greater Green River basin in southern Wyoming.

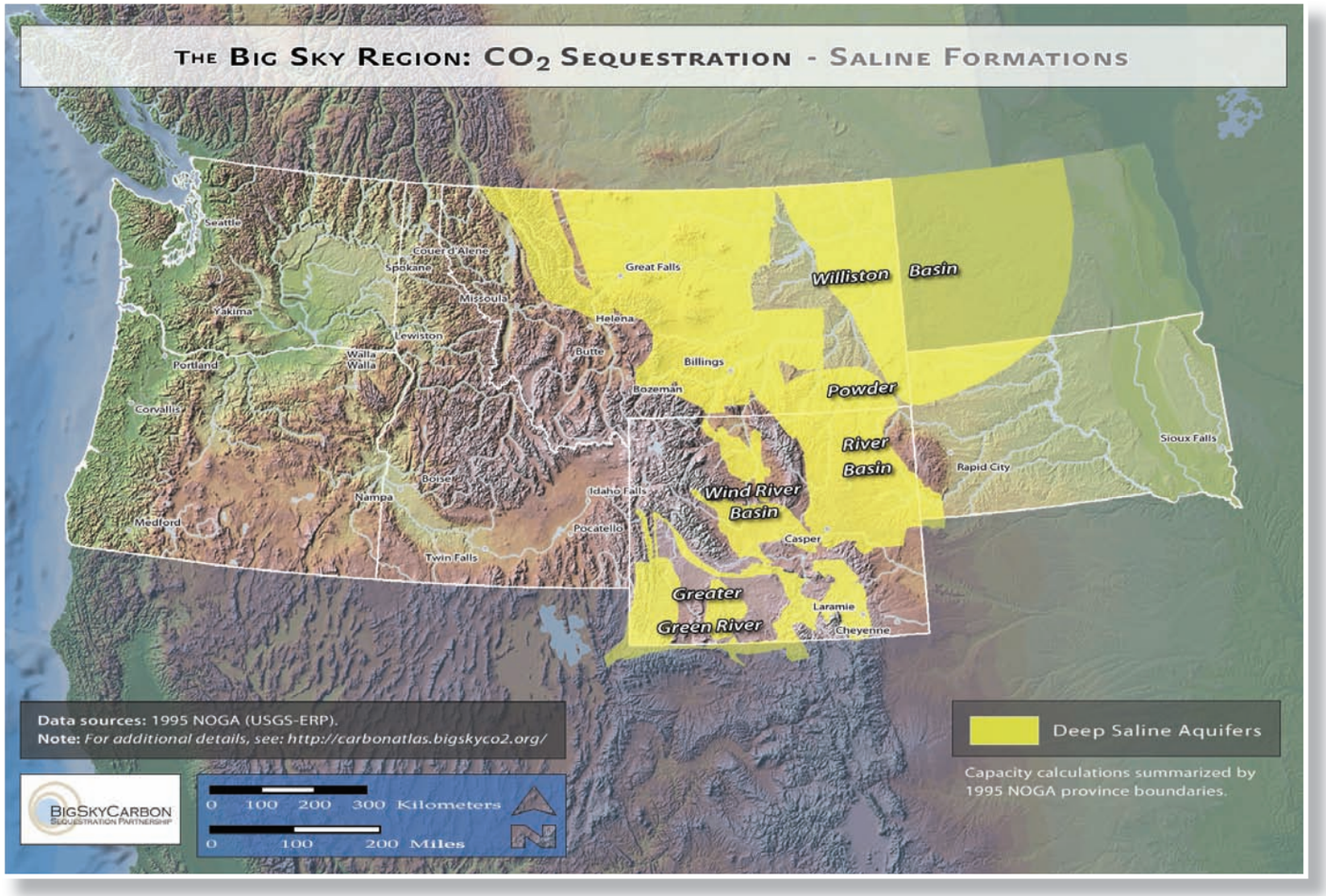
Three EOR operations are currently active in the Green River, Wind River and Powder River Basins utilizing CO_2 produced from a helium and methane gasification plant in the Green River Basin. Plans are in progress to expand the delivery of this CO_2 to many other fields including the Big Horn Basin, Williston Basin and Laramie Basin. The presence of large, naturally occurring CO_2 reservoirs in this Region further demonstrates the efficacy of use of these basins for long-term storage of CO_2.

Potential carbon sequestration volumes have been developed using information from a variety of sources including existing oil and gas wells and geographic extents of oil provinces and plays. The potential volumes total just under 1 billion metric tons (1.1 billion tons) of storage space for CO_2.





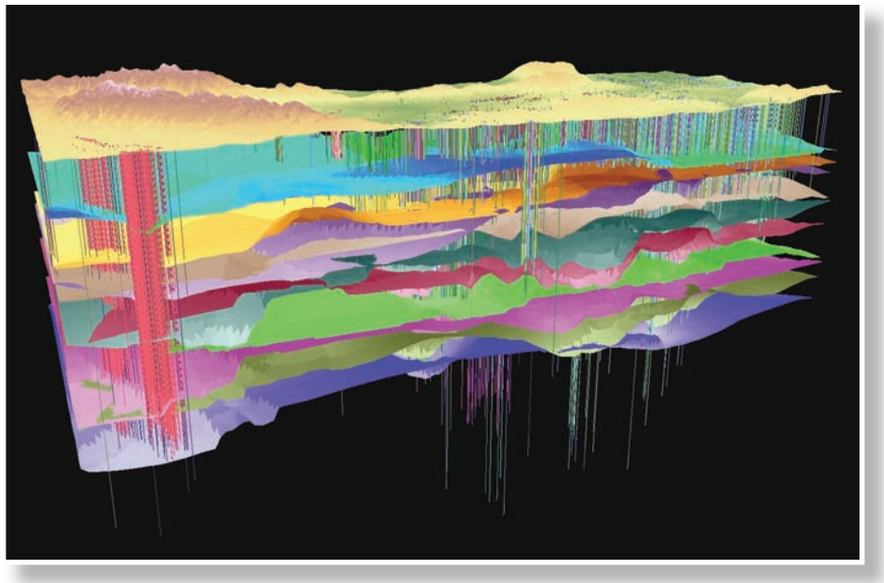




BSCSP Saline Formations

The extent of saline formations throughout the BSCSP Region offers great potential for future sequestration activities. Many of these formations currently host vast, naturally occurring CO_2 reservoirs that demonstrate the potential of these areas to hold anthropogenic CO_2 for millions of years.

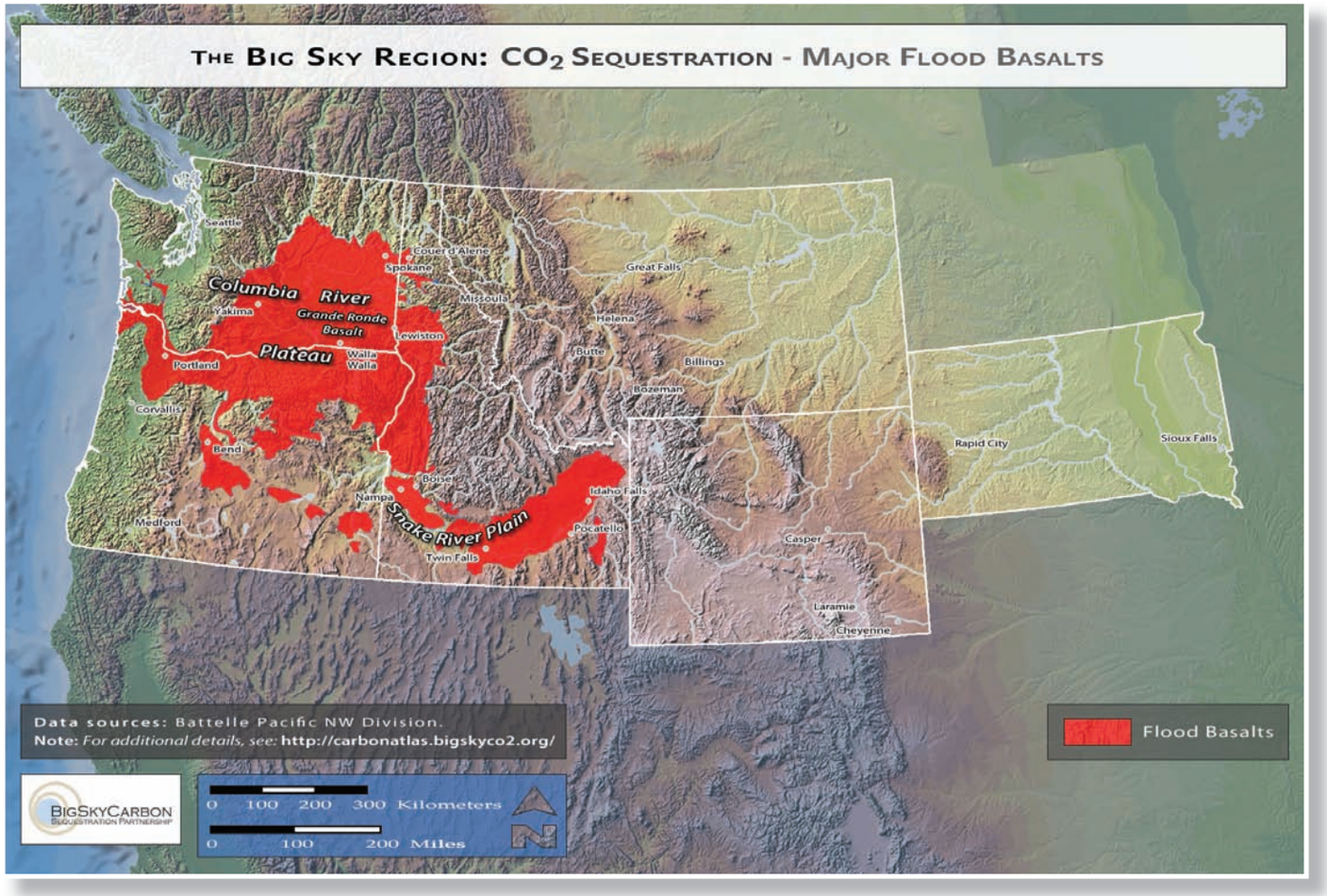
Many of these formations consist of reactive carbonate rocks that react with CO_2 to form calcium carbonate through various chemical and mineralization processes. The CO_2 is thereby converted to compounds that in effect, becomes part of the rock in the host formation. BSCSP is conducting work in the Lost Soldier oil and gas field in Wyoming to evaluate this process. The Lost Soldier field produces oil and gas from a reactive carbonate reservoir that has been undergoing CO_2 EOR for more than twenty years, facilitating the study of the consequences of long-term exposure of carbonate rocks to CO_2-rich fluids. Specifically, the BSCSP will be extracting cores from the formations that have been exposed to CO_2 over this period and determining mineralization rates to construct models to apply this information to other areas for future sequestration efforts. Rather than evaluating CO_2 EOR in this effort, BSCSP will determine the rate and extent of mineralization that occurs when reactive carbonate formations are injected with CO_2.



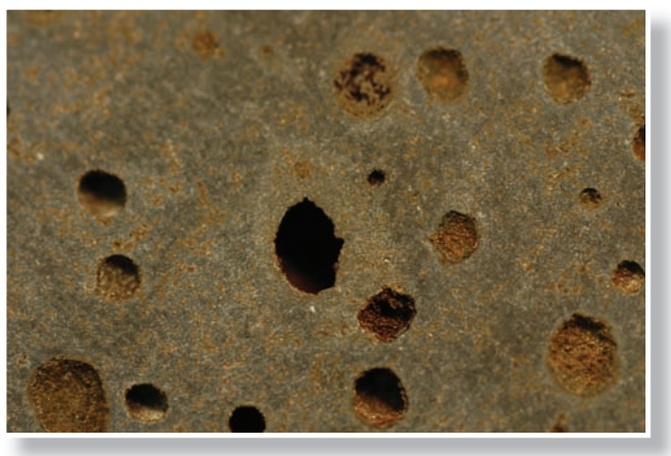
BSCSP Major Flood Basalts

Mafic volcanic (basalt) formations are a distinguishing feature of the region's geology. For example, the region's Columbia River Basalt Group covers approximately 164,000 km^2 (63,300 mi^2). Basalt formations offer significant long-term storage potential in the region, with conservative estimates of CO_2 storage capacity in the range of 33–134 billion metric tons (36–148 billion tons). Large basalt formations are globally distributed, with estimates that the 5 largest basalt provinces could sequester 10,000 years of world CO_2 emissions. Basalt formations have a number of characteristics favorable for storage of CO_2 including

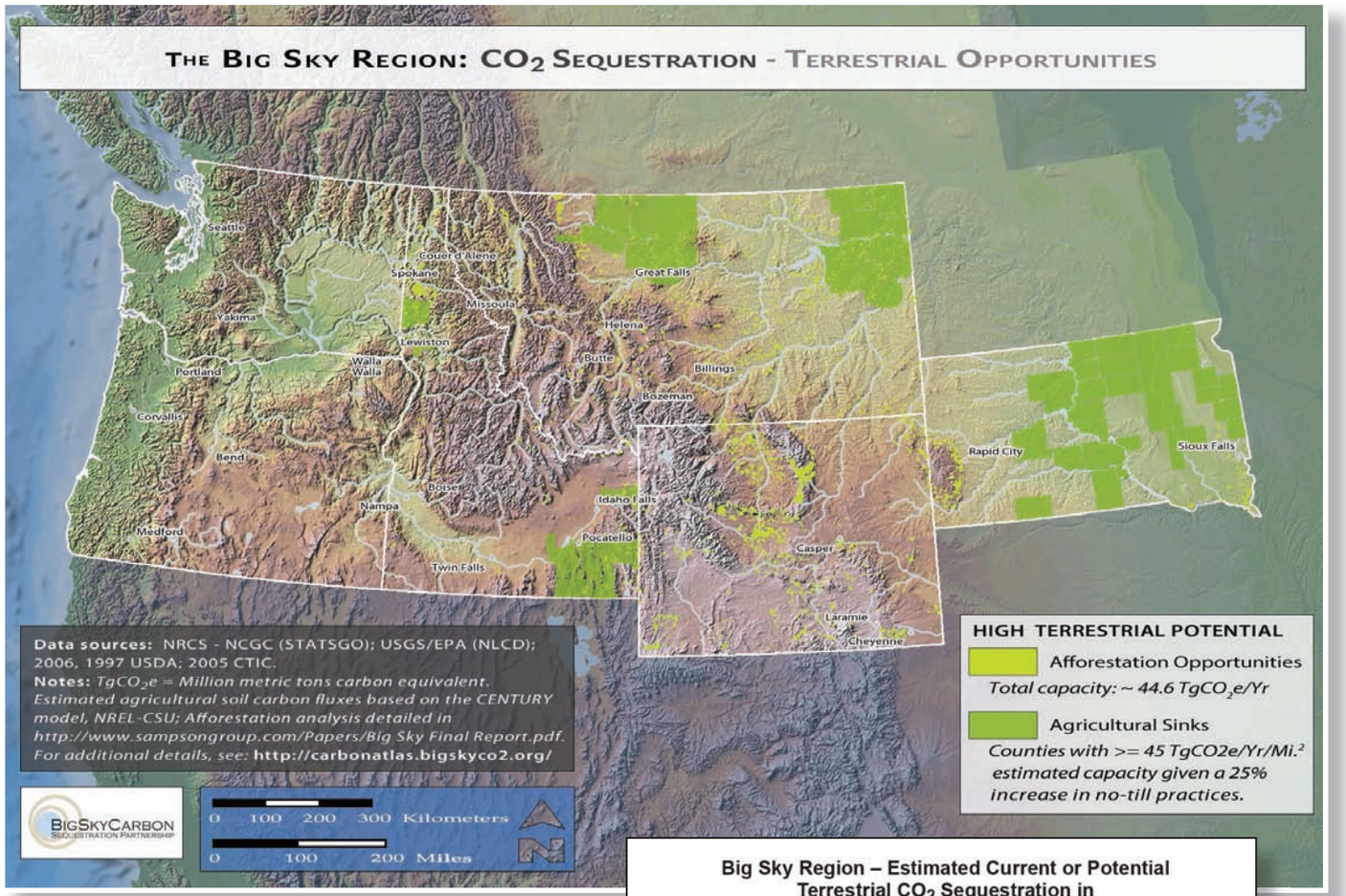
- Chemical makeup favorable for mineralization reactions
- Economic opportunity costs of using basalts are minimal
- Conducive mineralogy for sequestration
- Rapid conversion of CO_2 to carbonate
- High porosity and permeability



Basalt core samples



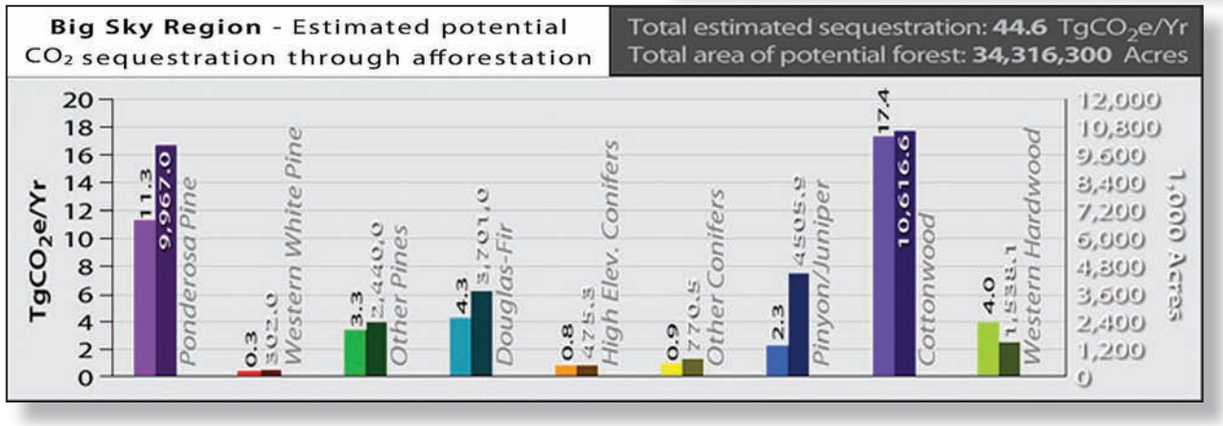
Magnified view of basalt core sample



Big Sky Region – Estimated Current or Potential Terrestrial CO_2 Sequestration in Metric Tons Carbon Equivalent (MTCE)

Agricultural:	*Scenario 1*	6691344
	Scenario 2	7572104
	Scenario 3	7062243
Afforestation Opportunities		44600000

Agricultural Scenarios: (1) Continuation of existing land use practices on currently associated areas; (2) 25% increase in area under no-till practices, at expense of areas under conventional tillage; (3) 25% increase in area under Conservation Reserve Program, at expense of areas under conventional tillage.



BSCSP Terrestrial Opportunities

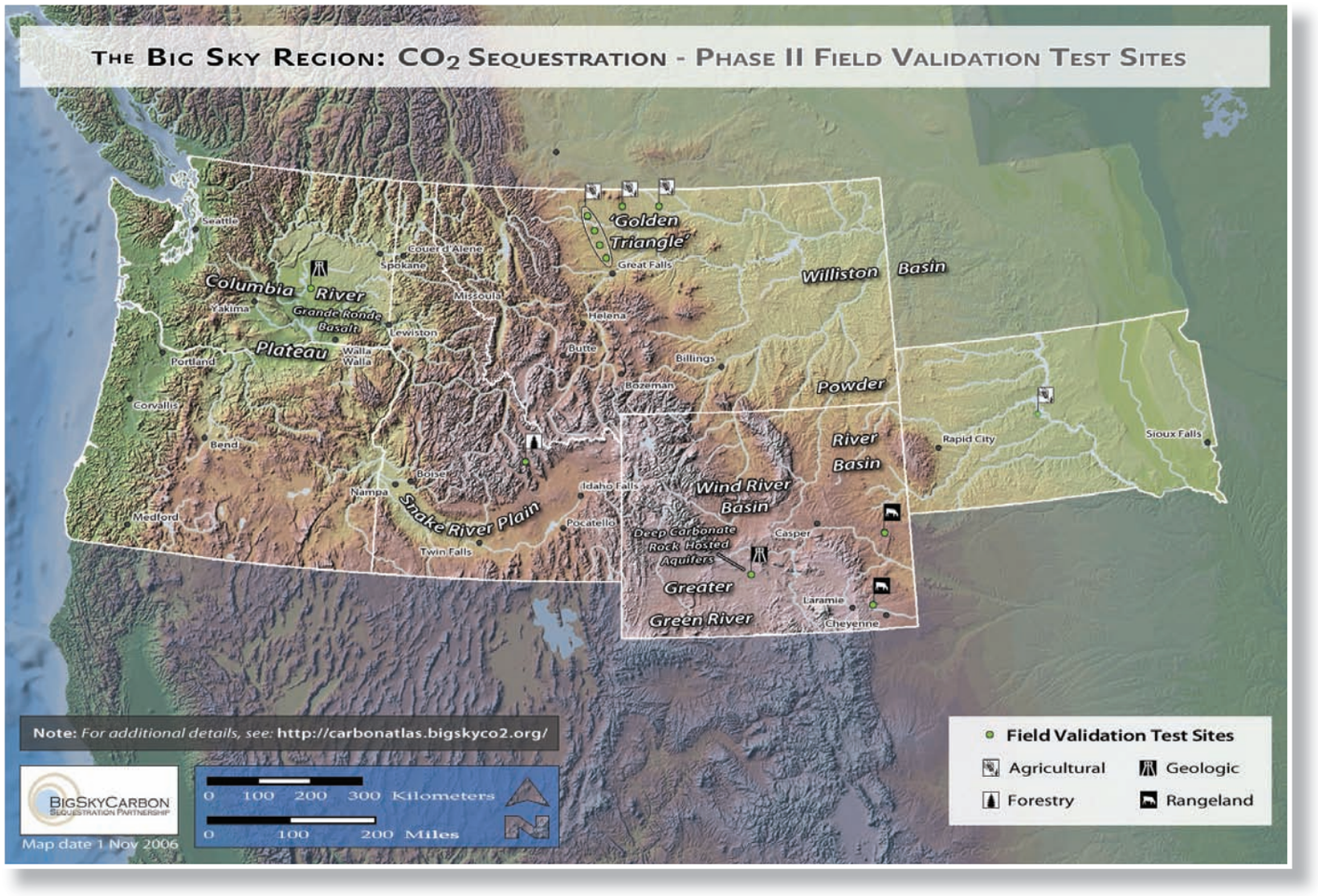
The BSCSP Region has extensive land area with land uses that provide tremendous potential for greenhouse gas (GHG) offsets through terrestrial carbon sequestration in forests, rangelands, and agricultural croplands. The Partnership has developed a market-based approach to carbon storage and verification protocols; established terrestrial pilots in cropland, forestland, and rangeland; designed carbon portfolios in conjunction with industry, tribal members, and landowners; and conducted a remote sensing study of management practices and adoption trends in north-central Montana.

The BSCSP is working directly with landowners to provide guidance on land-management practices that maximize carbon storage and to develop initial portfolios. The potential development and design of carbon markets is being explored via two parallel efforts: (1) the development of carbon market portfolios with individual landowners and land managers (led by the National Carbon Offset Coalition [NCOC]) and (2) the use of a computer simulation model to assess terrestrial carbon storage potential and carbon market opportunities at a county level (led by a team at the South Dakota School of Mines and Technology [SDSMT]).

To date, the Chicago Climate Exchange (CCX) has accepted 5,388 CO_2-eq metric tons (5,939 CO_2-eq tons) of forestry-based carbon credits in the pilot tribal portfolio. The projects are now undergoing third-party verification in preparation for listing on the CCX. An additional 2,000 CO_2-eq metric tons (2,200 CO_2-eq tons) is now under development with the Navajo nation. For the private/state lands portfolio, NCOC has obtained listing agreements for 19 cropland sequestration projects in north-central Montana with a total of 7,587 CO_2-eq metric tons (8,363 CO_2-eq tons).

BSCSP Field Tests

The BSCSP plans to conduct two geologic field tests in prominent geological formations located throughout the Region (basalt formations and sedimentary rock hosted saline formations) and a preliminary study related to a potential, future enhanced coal bed sequestration field test. The BSCSP's primary geologic effort is to demonstrate carbon storage in basalt rock formations. This field test will assess the mineralogical, geochemical, and hydrologic impact of injected CO_2 within a basalt formation, and it will incorporate site monitoring and verification activities. Core samples will be obtained to verify laboratory and computer simulation studies showing rapid onset of carbonate mineralization in basalts.



In a secondary effort, the BSCSP is conducting a Reactive Carbonate Reservoir Assessment examining long-term CO_2 mineralization rates in carbonate rocks in conjunction with ongoing, long-term EOR operations at the Lost Soldier and Wertz oil fields in south-central Wyoming. The assessment will focus on the consequences of long-term exposure of carbonate rocks to CO_2 rich fluids using pre-and post-injection core comparisons.

Finally, a limited amount of effort is being directed toward technical and economic issues associated with injecting a pure CO_2 stream into a coal seam and coal swelling effects on permeability changes. Work to date has focused on the design study that includes a technical evaluation to determine the advantages and disadvantages of injecting the flue gas versus a separated, relatively pure CO_2 gas stream.

The BSCSP will also determine each test site's operational needs, permitting, regulatory and monitoring requirements, and quantify economic offset opportunities such as EOR and CBM production.

Several terrestrial field tests are being performed. Cropland field tests are being conducted in the "golden triangle" region of north central Montana to (1) quantify and determine cropland management practices that optimize carbon sequestration and (2) develop MM&V protocols to evaluate carbon sequestration for enrolled farms. Rangeland field tests are being conducted to determine the effects of (1) grazing intensity and seasonality of grazing on native northern mixed-grass prairie near Cheyenne, Wyoming and (2) improvement practices on degraded northern mixed-grass prairie near Lusk, Wyoming. A field test is also planned to quantify sequestration potential in forests through understanding the effects of forest management on different carbon pools in forests.